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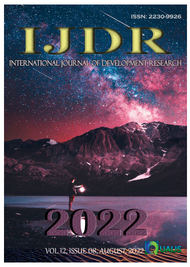

RESEARCH ARTICLE OPEN ACCESS

UNSTEADY MHD FREE CONVECTIVE FLUID FLOW EMBEDDED IN A POROUS MEDIUM WITH HEAT SOURCE IN THE PRESENCE OF SORET AND RADIATION EFFECTS

Dr. Sk. Nuslin Bibi*, G. Padma and Dr. Md. Mohammed Ali

Department of Freshman Engineering, Geethanjali College of Engineering and Technology, Hyderabad, India

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Corresponding author:
Dr. Sk. Nuslin Bibi,

ABSTRACT

The present research paper aims to study the effect of soret and radiation effects on an MHD convective fluid flow embedded in a porous medium with heat source. Dimensional non-linear coupled differential equations transformed into dimensional less by introducing similarity variables Time-dependent suction is assumed and the radiative flux is described using the differential approximation for radiation. The Galerkin finet element method is used to solve the equations governing flow. The flow phenomenon has been characterized with the help of flow parameters such as velocity, temperature and concentration profiles for different parameters such as. Schmidt number, Prandtl number, Magnetic field, Heat source, Permeability parameter, Thermal radiation, Chemical reaction, Modified Grashof number, Soret number, Eckert number and Grashof number. The velocity, temperature and concentration are shown graphically. The coefficient of skin-friction, Nusselt number and Sherwood number are shown in tables.

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INTRODUCTION

In recent years many researchers are showing interest to study the Soret and radiation effects on embedded in a porous medium with heat source with unsteady MHD free convective fluid flow. The problem of fluid in an electromagnetic field has been studies for its importance in geophysics. Aerodynamic extrusion, metallurgy and other engineering process are used in petroleum engineering, chemical engineering, composite or ceramic engineering and heat dealing with heat flow and mass transfer over a vertical porous plate with variable suction, heat absorption. In the atmosphere, quasi – solid bodies, such as earth and so on heat and mass transfer phenomenon is observed.

Absorbed the Unsteady free-convection interaction with thermal radiation in vertical porous plate, Magnetic field, with constant suction and constant heat flux, heat generation and thermal and etc. [1-4]. Boundary layer flows with Dofour and soret effects on steady MHD combined free forced convective and mass transfer flow [5-7]. Numerical solutions of heat and mass transfer effects of an unsteady MHD free convective flow past an infinite vertical plate with constant suction [8]. convection heat transfers from an Isothermal vertical surface to a fluid saturated thermally satisfied porous medium [9-11]. studied about Unsteady MHD convective heat and mass transfer past a semi-infinite vertical permeable moving plate with heat absorption [12]. Effect of mass transfer on flow past impulsively started infinite vertical plate with a constant heat flux and chemical reaction [13-15]. MHD Oscillatory Flow on Free Convection-radiation through a Porous medium with constant suction velocity, in a fluid saturated porous medium with uniform surface heat flux, the nature of vertical natural convection flow resulting from the combined buoyancy effects of thermal and mass diffusion, Free convection flow with mass transfer [16-18]. Heat transfer, Thermal Radiation, viscous flow past an impulsively started semi-infinite horizontal plate, Effects of Hall current and heat transfer on rotating flow of a second grade fluid through a porous medium [19]. Numerical solution of differential equation, suction r injection, viscosity effects [20]. Chemical Reactions, Soret and dufour effects, stretching surface in porous medium, vertical plate with heat and mass transfer, Chemical reaction effects on vertical oscillating plate with variable temperature, Natural convection caused by immersing a hot surface in a fluid saturate porous medium at constant ambient temperature, Natural convection caused by immersing a hot surface in a fluid saturate porous medium at constant ambient temperature, heat transfer mechanisms, In this paper, Unsteady MHD Free Convective Fluid Flow Embedded in a Porous Medium with Heat Source in the presence of Soret and Radiation Effects of uniform magnetic field applied normal to the flow has been studied. The process is governed by the non-linear system of partial differential equations whose exact solutions are difficult to obtain, if possible. so, Galerkin finite element method has been adopted for its solution, which is more economical from computational point view.

Mathematical Formulation

Consider the problem of unsteady two-dimensional, laminar, boundary layer flow of a viscous, incompressible, electrically conducting fluid along a semi-infinite vertical plate in the presence of thermal and concentration buoyancy effects. In the normal flow time dependent suction is considered. The x'-axis is taken along the plate in the direction of the flow and y'-axis normal to it. Further, due to the semi-infinite plane surface assumption the flow variables are the functions of normal distances y' and t' only. A uniform magnetic field is applied normal to the direction of the flow. Now, by Boussinesq's approximation, the following governing equations of the flow process are:

Continuity equation:

$$\frac{\partial v'}{\partial y'}=0 \quad \text{……………………………(1)}$$

Momentum equation:

$$\frac{\partial u'}{\partial t'}+v'\frac{\partial u'}{\partial y'}=g\beta(T'-T'_{\infty})+g\beta^{*}(C'-C'_{\infty})+v\frac{\partial^2 u'}{\partial y'^2}-\frac{v}{K'}u'-\frac{\sigma B_O^2}{\rho'}u' \quad \text{……………………………(2)}$$

Energy Equation:

$$\frac{\partial T'}{\partial t'}+v'\frac{\partial T'}{\partial y'}=v\frac{\partial^2 T'}{\partial y'^2}-\frac{1}{\rho c_p}\frac{\partial q'_r}{\partial y'}-Q_o(T'-T'_{\infty})+\frac{v}{c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \quad \text{……………………………(3)}$$

Concentration Equation:

$$\frac{\partial C'}{\partial t'}+v'\frac{\partial C'}{\partial y'}=v\frac{\partial^2 C'}{\partial y'^2}-K_r'^2 C'+\frac{D_m k_T}{T_m}\frac{\partial^2 T'}{\partial y'^2} \quad \text{……………………………(4)}$$

The boundary conditions for the velocity, temperature and concentration fields are:

$$t>0, u'=1, \qquad T'=T'_{\infty}+\varepsilon(T'_W-T'_{\infty})e^{n't'}, C'=C'_{\infty}+\varepsilon(C'_W-C'_{\infty})e^{n't'} \quad at \quad y'=0$$
$$u'\to 0, \qquad T'\to T'_{\infty}, \qquad C'\to C'_{\infty}, \qquad as \quad y'\to\infty \quad \text{……………………………(5)}$$

Where T'_W and C_W Dimensional temperature and concentration respectively, T'_W and C_W are the free stream Dimensional temperature and concentration respectively.

The radiative heat flux term by using the Rosseland approximation is given by

$$q'_r=-\frac{4\sigma'}{3k'_1}\frac{\partial T'^4}{\partial y'} \quad \text{……………………………(6)}$$

All the variables are defined in the nomenclature. It is assumed that the temperature differences within the flow are sufficiently small so that T^4 can be expanded in a Taylor series about the free stream temperature T_∞ so that after rejecting higher order terms:

$$T^4\approx 4T'^3_{\infty}T'-3T'^4_{\infty} \quad \text{……………………………(7)}$$

The energy equation after substitution of Equ (6) and (7) can now be written as

$$\frac{\partial T'}{\partial t'}+v'\frac{\partial T'}{\partial y'}=\frac{k}{\rho c_p}\frac{\partial^2 T'}{\partial y'^2}+\frac{16\sigma' T_{\infty}^3}{3\rho c_p k'}\frac{\partial^2 T'}{\partial y'^2}-Q_o(T'-T'_{\infty})+\frac{v}{c_p}\left(\frac{\partial u'}{\partial y'}\right)^2 \quad \text{……………………………(8)}$$

From Eq. (1) one can see that the suction is a function of time only. Hence, it is assumed to be in the following form:

$$v' = -V_O(1+\varepsilon A e^{n't'})$$ ………………………….(9)

Where A is the suction parameter and $\varepsilon A << 1$. Here V_O is mean suction velocity, which is a non-zero positive constant and the minus sign indicates that the suction is towards the plate. It is now convenient to introduce the following dimensionless parameters:

$$u = \frac{u'}{U_o},\ y = \frac{U_o y'}{\nu},\ t = \frac{t' U_o^2}{\nu},\ P_\Gamma = \frac{\rho c_p \nu}{k},\ S_c = \frac{\nu}{D},\ T = \frac{T' - T'_\infty}{T'_w - T'_\infty},\ C = \frac{C' - C'_\infty}{C'_w - C'_\infty},\ K = \frac{K' U_o^2}{\nu^2},$$
$$n = \frac{\nu n'}{U_o^2},\ G_\Gamma = \frac{g\beta\nu (T'_w - T'_\infty)}{U_o^3},\ G_m = \frac{\nu g \beta^* (C'_w - C'_\infty)}{U_o^3},\ Q = \frac{Q_o \nu}{U_o^2},\ M = \frac{\sigma B_o^2 \nu}{\rho U_o^2},\ K_\Gamma^2 = \frac{K_\Gamma^2 \nu}{U_o^2}$$
$$S_O = \frac{D_m k_T (T'_w - T'_\infty)}{\nu T_m (C'_w - C'_\infty)},\ E_C = \frac{\nu_o'^2}{C_p (T'_w - T'_\infty)},\ N_\Gamma = \frac{16\sigma' T_\infty^3}{3k'k}$$ …….. (10)

On substituting of Eq. (9) into Eqs. (2), (4) and (7), the following governing equations are obtained in non-dimensional form:

$$\frac{\partial u}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial u}{\partial y} = G_\Gamma T + G_m C + \frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K}\right)u$$ ……………………… (11)

$$\frac{\partial T}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial T}{\partial y} = \left(\frac{1+N_\Gamma}{P_\Gamma}\right)\frac{\partial^2 T}{\partial y^2} - QT + E_C\left(\frac{\partial u}{\partial y}\right)^2$$ ………………………(12)

$$\frac{\partial C}{\partial t} - \left(1+\varepsilon A e^{nt}\right)\frac{\partial C}{\partial y} = \frac{1}{S_C}\frac{\partial^2 C}{\partial y^2} + So\frac{\partial^2 T}{\partial y^2} - K_\Gamma^2 C$$ ……………………….(13)

where G_Γ, G_m, P_Γ, N_Γ, E_C, S_C, K, S_Γ, K_Γ, M and Q are the thermal Grashof number, Modified Grashof Number, Prandtl Number, Radiation parameter, Eckert number, Schmidt number, Permiability parameter, Soret number, Chemical reaction parameter,Magnetic parameter and Heat source parameter respectively.

The corresponding boundary conditions are:

$$u=1,\quad T=1+\varepsilon e^{nt}, C=1+\varepsilon e^{nt} \quad on\ y=0$$
$$u \to 0, T \to 0, C \to 0 \quad as\ y \to \infty$$ …………………….(14)

The mathematical formulation of the problem is now completed. Equations. (11) -(13) are coupled non-linear systems of partial differential equations, and are to be solved by using the initial and boundary conditions given in eq. (14). However, exact solutions are difficult if possible. Hence these equations are solved by Galerkin finite element method.

Method of solution

Applying the Galerkin finite element method for Equations. (11) Over the element (e) $(y_j \le y \le y_k)$ is:

$$\int_{y_J}^{y_K} N^{(e)^T}\left(\frac{\partial^2 u^{(e)}}{\partial y^2} + B\frac{\partial u^{(e)}}{\partial y} - \frac{\partial u^{(e)}}{\partial t} - Nu^{(e)} + R_1\right)dy = 0$$ ………………………(15)

Where $B = 1 + \varepsilon A e^{nt}$ $R_1 = G_\Gamma T + G_m C$ $N = M + \frac{1}{K}$

Integrating the first term in equation (15) by parts, one obtains

$$\left. N^{(e)^T}\frac{\partial u^{(e)}}{\partial y}\right\}_{y_j}^{y_K} - \int_{y_j}^{y_K}\left\{\frac{\partial N^{(e)^T}}{\partial y}\frac{\partial u^{(e)}}{\partial y} - N^{(e)^T}\left(B\frac{\partial u^{(e)}}{\partial y} + \frac{\partial u^{(e)}}{\partial t} + Nu^{(e)} - R_1\right)\right\}dy = 0$$
……………………….(16)

Neglecting the first term in equation (16) we gets

$$\int_{y_j}^{y_K}\left\{\frac{\partial N^{(e)^T}}{\partial y}\frac{\partial u^{(e)}}{\partial y} - N^{(e)^T}\left(B\frac{\partial u^{(e)}}{\partial y} - \frac{\partial u^{(e)}}{\partial t} - Nu^{(e)} + R_1\right)\right\}dy = 0$$

Let $u^{(e)} = N^{(e)}\phi^{(e)}$ be the linear piecewise approximation solution over the element (e), $(y_j \le y \le y_k)$ where

$N^{(e)} = [N_j N_k]$, $\phi^{(e)} = [u_j u_k]^T$ and $N_j = \dfrac{y_k - y}{y_k - y_j}$, $N_k = \dfrac{y - y_j}{y_k - y_j}$, are the basic functions. One obtains:

$$\frac{1}{l^{(e)}}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{bmatrix} u_j \\ u_k \end{bmatrix} - \frac{B}{2}\begin{bmatrix} -1 & 1 \\ -1 & 1 \end{bmatrix}\begin{bmatrix} u_j \\ u_k \end{bmatrix} + \frac{l_{(e)}}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} u_j^{\bullet} \\ u_k^{\bullet} \end{bmatrix} + \frac{Nl^{(e)}}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} u_j \\ u_k \end{bmatrix} = R_1 \frac{l_{(e)}}{2}\begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

Where dot denotes the differentiation with respect to t. Assembling the element equations for two consecutive elements $y_{i-1} \le y \le y_i$ and $y_i \le y \le y_{i+1}$, following is obtained

$$\frac{1}{l^{(e)^2}}\begin{bmatrix} 1 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} - \frac{B}{2l^{(e)}}\begin{bmatrix} -1 & 1 & 0 \\ -1 & 0 & 1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} + \frac{1}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} u_{i-1}^{\bullet} \\ u_i^{\bullet} \\ u_{i+1}^{\bullet} \end{bmatrix} + \frac{N}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} = \frac{R_1}{2}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \quad \text{.................(17)}$$

Now put row corresponding to the node i to zero, from equation (17) the difference schemes is

$$\frac{1}{l^{(e)^2}}\left[-u_{i-1} + 2u_i - u_{i+1}\right] - \frac{B}{2l^{(e)[\,]}}\left[-u_{i-1} + u_{i+1}\right] + \frac{1}{6}\left[u_{i-1}^{\bullet} + 4u_i^{\bullet} + u_{i+1}^{\bullet}\right] + \frac{N}{6}\left[u_{I-1} + 4u_i + u_{i+1}\right] = R_1$$

Applying the Trapezoidal rule, following system of equations in Crank-Nicholson method are obtained:

$$A_1 u_{i-1}^{j+1} + A_2 u_i^{j+1} + A_3 u_{i+1}^{j+1} = A_4 u_{i-1}^j + A_5 u_i^j + A_6 u_{i+1}^j + R^* \quad \text{.........................(18)}$$

Where

$$A_1 = 2 - 6r + 3Brh + Nk \quad A_2 = 8 + 12r + 4Nk \quad A_3 = 2 - 6r - 3Brh + Nk$$
$$A_4 = 2 + 6r - 3Brh - Nk \quad A_5 = 8 - 12r - 4Nk \quad A_6 = 2 + 6r + 3Brh - Nk$$
$$R^* = 12(G_\Gamma)kT_i^j + 12(G_m)kC_i^j$$

Applying similar procedure to equation (12) and (13) then we gets

$$B_1 T_{i-1}^{j+1} + B_2 T_i^{j+1} + B_3 T_{i+1}^{j+1} = B_4 T_{i-1}^j + B_5 T_i^j + B_6 T_{i+1}^j + R^{**} \quad \text{........................(19)}$$

$$C_1 C_{i-1}^{j+1} + C_2 C_i^{j+1} + C_3 C_{i+1}^{j+1} = C_4 C_{i-1}^j + C_5 C_i^j + C_6 C_{i+1}^j + R^{***} \quad \text{........................(20)}$$

Where

$$B_1 = 2 - 6Dr + 3Brh + Qk \qquad B_2 = 8 + 12Dr + 4Qk$$
$$B_3 = 2 - 6Dr - 3Brh + Qk \qquad B_4 = 2 + 6Dr - 3Brh - Qk$$
$$B_5 = 8 - 12Dr - 4Qk \qquad B_6 = 2 + 6Dr + 3Brh - Qk \quad R^{**} = 12rE_C(u[i+1] - u[i])^2$$
$$C_1 = 2S_C - 6r + 3BS_C rh + ES_C k \qquad C_2 = 8S_C + 12r + 4ES_C k$$
$$C_3 = 2S_C - 6r - 3BS_C rh + ES_C k \qquad C_4 = 2S_C + 6r - 3BS_C rh - ES_C k$$
$$C_5 = 8S_C - 12r - 4ES_C k \qquad C_6 = 2S_C + 6r + 3BS_C rh - ES_C k$$
$$R^{***} = 12rS_C S_o(T[i-1] - 2T[i] + T[i+1])$$

Here $r = \dfrac{k}{h^2}$, $D = \dfrac{1+N_\Gamma}{P_\Gamma}$, $E = K_\Gamma^2$ and h, k are the mesh sizes along y-direction and time t -direction respectively. Index i refers to the space and j refers to the time. In Equations (18)-(20), taking i = 1(1) n and using initial and boundary conditions (14), the following system of equations are obtained:

$$A_i X_i = B_i \qquad i = 1(1)3 \quad \text{................................(21)}$$

Where A_i's are matrices of order n and X_i, B_i's column matrices having $n-$ components. The solutions of above system of equations are obtained by using Thomas algorithm for velocity, temperature and concentration. Also, numerical solutions for these equations are obtained by C-program. In order to prove the convergence and stability of finite element method, the same C-program was run with slightly changed values

Skin friction: The skin-friction, Nusselt number and Sherwood number are important physical parameters for this type of boundary layer flow.

The skin friction, rate of heat and mass transfer are

Skin friction coefficient (C_f) at the plate is $C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0}$ ....(22)

Nusselt number (Nu) at the plate is $Nu = \left(\frac{\partial T}{\partial y}\right)_{y=0}$ ....(23)

Sherwood number (Sh) at the plate is $Sh = \left(\frac{\partial C}{\partial y}\right)_{y=0}$ ....(24)

RESULTS AND DISCUSSION

The formulation of the problem that accounts for the effects of the Soret and Radiation reaction on an unsteady MHD flow past a semi-infinite vertical porous plate with Heat source is performed in the preceding sections. The governing equations of the flow field are solved analytically by using a finite element method. The expressions for the velocity, temperature, concentration, skin-friction, Nusselt number, and Sherwood number are obtained. To get a physical perception of the problem, the above physical quantities are computed numerically for different values of the governing parameters, viz., the Grashof thermal number Gr , the Modified Grashof number G_m, the magnetic parameter M ,the thermal radiation the permeability parameter K , the Prandtl number Pr , the heat source parameter Q , the Eckert number Ec , the Schmidt number Sc , the chemical reaction parameter Kr , the soret numder So . Here we fixed $\varepsilon = 0.02, n = 0.5, t = 1.0$

The effects of various governing parameters on the skin friction coefficient C_f, Nusselt number Nu and the Sherwood number Sh are shown in Tables 1, 2 and 3. From Table 1, it is noticed that as G or G_m increases, the skin friction coefficient increases. It is obvious that as Mor K increases, the skin friction coefficient decreases. From Table 2, it is observed that an increase in the Q or the Pr Prandtl snumber reduces the skin friction and increases the Nusselt number. Also, it is found that as $Ec$and Nr increases the skin friction increases and the Nusselt number increases. From Table 3, it is found that as Sc or Kr increases, the skin friction coefficient decreases and the Sherwood number decreases. Also, it is found that as So increases the skin friction increases and the Sherwood number increases.

Table 1. Effect of Gr ,G_m , M and K on C_f (Nr =0.5, Q =1.0, Pr=0.71, Ec=0.001, Sc=0.22, So=1.0, Kr =0.5)

Gr	G_m	M	K	C_f
5.0	5.0	0.5	1.0	3.7681
10.0	5.0	0.5	1.0	4.9583
5.0	10.0	0.5	1.0	4.2746
5.0	5.0	1.0	1.0	2.3275
5.0	5.0	0.5	2.0	2.9958

Table 2: Effect of Q , Pr Nr and Ec on C_f and Nu (Gr =5.0, G_m =5.0, M=0.5, K =1.0, Sc=0.22, So=1.0, Kr =0.5)

Q	Pr	Nr	Ec	C_f	Nu
1.0	0.71	0.5	0.001	3.7681	1.6513
2.0	0.71	0.5	0.001	3.1542	1.5324
1.0	7.0	0.5	0.001	2.8564	1.1258
1.0	0.71	1.0	0.001	4.2654	2.5413
1.0	0.71	0.5	0.01	3.8916	1.8645

Table 3: Effect of Sc , So and Kr on C_f and Sh (Gr =5.0, G_m =5.0, M=0.5, K=1.0, Q =1.0, Pr=0.71, Nr =0.5, Ec=0.001)

Sc	So	Kr	C_f	Sh
0.22	1.0	0.5	3.7681	1.4256
0.60	1.0	0.5	3.2132	1.2546
0.22	2.0	0.5	3.9245	1.6524
0.22	1.0	1.0	3.1542	1.0984

Figs 1(a) and 1(b) illustrate the velocity and temperature profiles for different values of Heat source parameter Q , the numerical results show that the effect of increasing values of heat source parameter result in a decreasing velocity and temperature.

Figs 2(a) and 2(b) illustrates the behavior Velocity and Temperature for different values of Thermal radiation parameter Nr . It is observed that an increase in Nr contributes to increase in both the values of velocity and Temperature.

The influence of the thermal Grashof number Gr on the velocity is presented in figure .3. Increase in the Grashof number Gr contributes to the increase in velocity when all other parameter that appears in the velocity field are held constant The influence of the solutel Grashof number Gm on the velocity is presented in figure.4.It is observed that, while all other parameters are held constant and velocity increases with an increase in

solute Grashof number G_m. Figs 5(a) and 5(b) illustrate the velocity and temperature profiles for different values of the Prandtl number P_r. The Prandtl number defines the ratio of momentum diffusivity to thermal diffusivity. The numerical results show that the effect of increasing values of Prandtl number results in a decreasing velocity (Fig 5(a)). From Fig 5 (b), it is observed that an increase in the Prandtl number results a decrease of the thermal boundary layer thickness and in general lower average temperature within the boundary layer.
The velocity and temperature profiles are shown in Figs 6(a) and 6(b) for different values of Eckert number E_c. An increase in Eckert number E_C leads to increase in both velocity and temperature. For various values of the magnetic parameter M, the velocity profiles are plotted in Fig 7. It can be seen that as M increases, the velocity decreases. This result qualitatively agrees with the expectations, since the magnetic field exerts a retarding force on the flow.

The effect of the permeability parameter K on the velocity field is shown in Fig 8. An increase in the resistance of the porous medium which will tend to increase the velocity. Thipps behavior is evident from Fig 8. Figs 9(a) and 9(b) respectively. The Schmidt number embodies the ratio of the momentum to the mass diffusivity. The Schmidt number S_c therefore quantifies the relative effectiveness of momentum and mass transport by diffusion in the hydrodynamic (velocity) and concentration (species) boundary layers. As the Schmidt number S_C increases the concentration decreases. This causes the concentration buoyancy effects to decrease yielding a reduction in the fluid velocity. The reductions in the velocity and concentration profiles are accompanied by simultaneous reductions in the velocity and concentration boundary layers. These behaviors are clear from Figs 9(a) and 9(b).
Fig 10(a) depict the velocity profiles for different values of the Soret number S_o. The Soret number defines the effect of the temperature gradients inducing significant mass diffusion effects. It is noticed that velocity profile for $K_\Gamma = 0.5, G_\Gamma = G_m = 5, K = 1.0, N_\Gamma = 0.5, S_c = 0.22, P_\Gamma = 0.71$. are compared with the available solution of Mohamed [60] in Fig 10(a). It observed that the present results are in good agreement with that of Mohamed. Fig 10(b) depicts the concentration profiles for different values of the Soret number S_o It is noticed that an increase in the Soret number results in an decrease concentration within the boundary layer. Figs 11(a) and 11(b) illustrates the behavior velocity and concentration for different values of chemical reaction parameter K_r. It is observed that an increase in leads to a decrease in both the values of velocity and concentration.

$$\begin{pmatrix} S_C = 0.22, \varepsilon = 0.02, P_\Gamma = 0.71, M = 0.5, G_\Gamma = 5, G_m = 5, S_O = 1, \\ K_\Gamma = 0.5, K = 1, E_C = 0.001, t = 1.0, N_\Gamma = 0.5, n = 0.5, A = 0.3 \end{pmatrix}$$

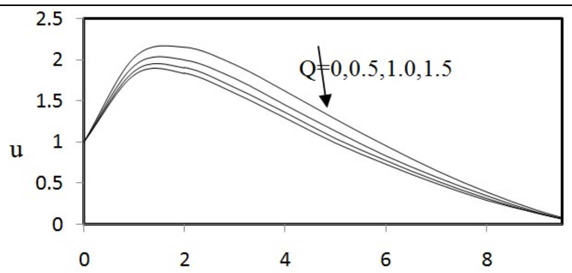

Fig.1(a). Effets of Heat source Q on the Velocityprofile

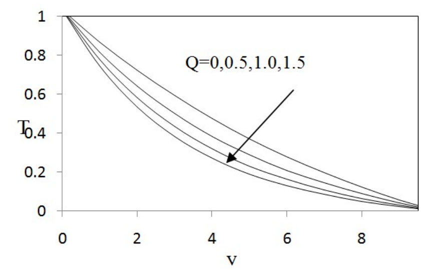

Fig.1 (b). Effets of Heat source Q on the Temperature profile

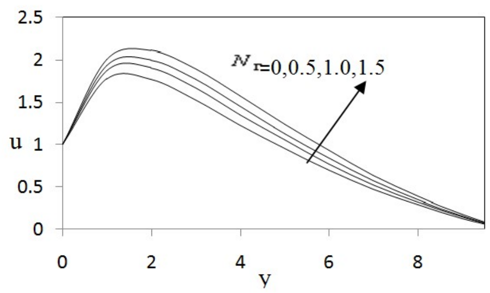

Fig.2(a) Effets of Thermal radiation N_r on the Velocity profile

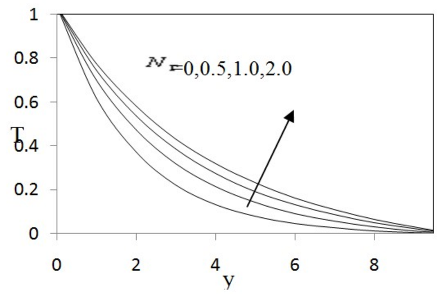

Fig.2(b) Effets of Thermal radiation N_r on the Temperature profile

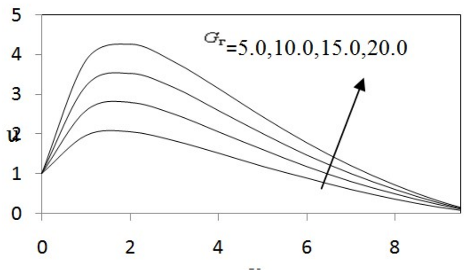

Fig. 3. Effects of Grashof number G_r on Velocity profile

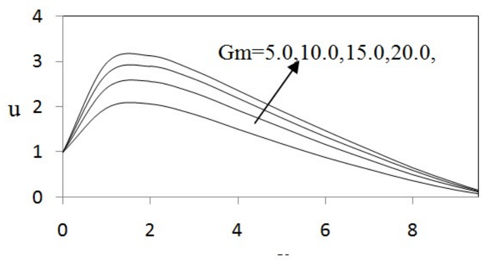

Fig. 4. Effects of solutel Grashof number G_m on Velocity profile.

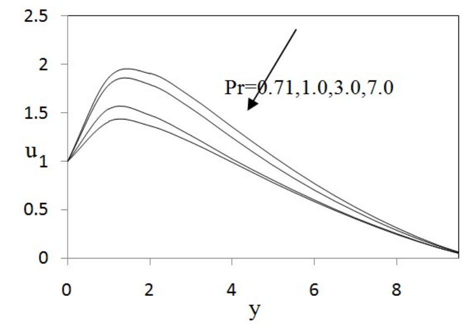

Fig.5(a). Effects of Prandtl number P_r on Velocity profile

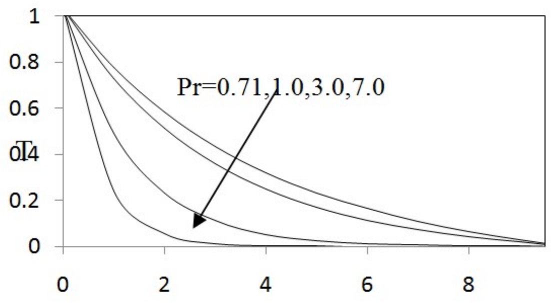

Fig. 5(b). Effets of Prandtl number P_r on the Temperature profile

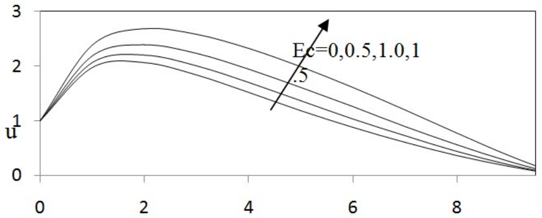

Fig. 6(a). Effets of Eckert number E_C on the Velocity profile

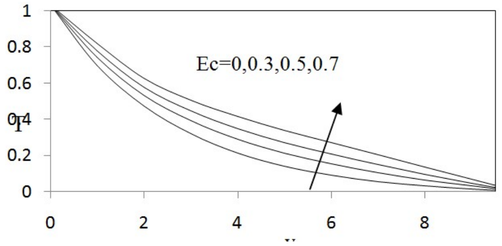

Fig.6(b) Effets of Eckert number E_c on the Temperature profile

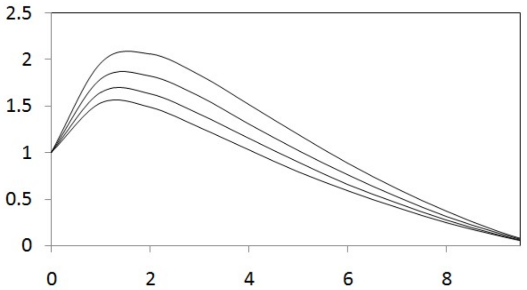

Fig.7. Effets of Magnetic parameter M on Velocity profile

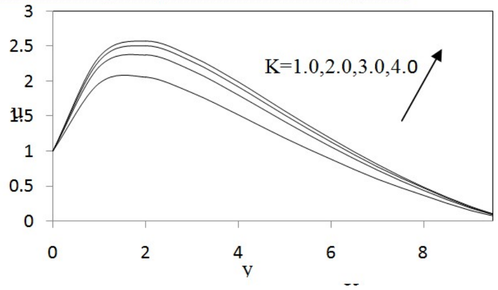

Fig. 8. Effects of Permeability parameter K on Velocity profile

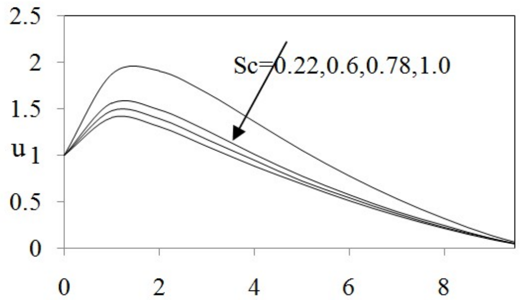

Fig. 9(a) Effets of Schmidt number S_c on the Velocity profile

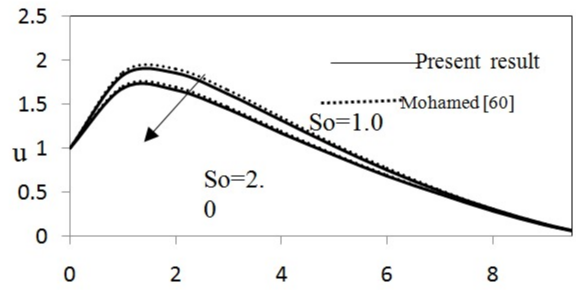

Fig.9(b) Effets of Schmidt number S_C on the Concentration profile

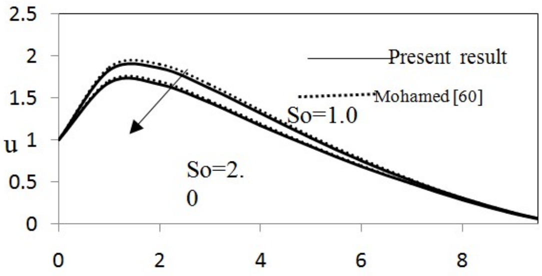

Fig.10(a) Effets of oret number S_o on the velocity profile

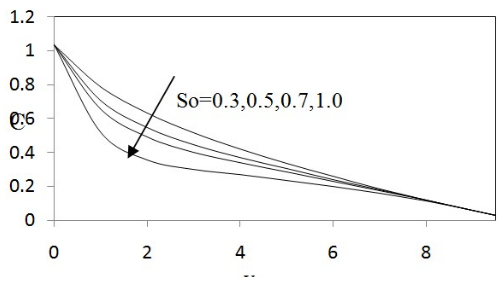

Fig. 10(b). Effets of Soret number S_O on Concentration profile

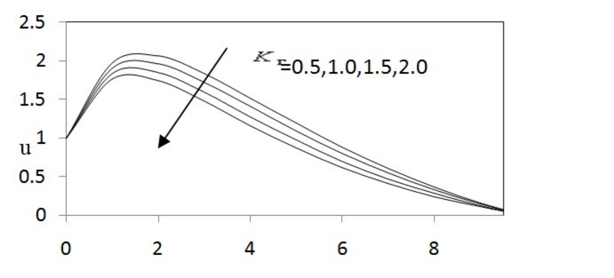

Fig.11(a).Effets of Chemical reaction K_Γ on velocity profile

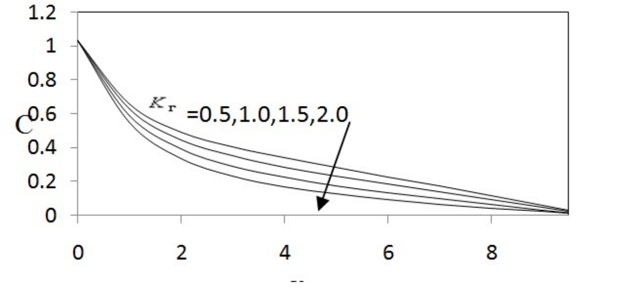

Fig.11(b). Effets of Chemical reaction K_Γ on the Concentration profile

CONCLUSIONS

The problem of two-dimensional fluid in the prances of thermal and concentration buoyancy effects under the influence of uniform magnetic field applied normal to the flow is formulated and solved numerically. A Galerkin finite element method is adopted to solve the equations governing the flow. The results illustrate the flow characteristics for the velocity, temperature, concentration, skin-friction, Nusselt number, and Sherwood number. The conclusions of the study are as follows:

- The velocity increases with the increase Thermal Grashof number and Modified Grashof number.
- The velocity decreases with an increase in the Magnetic parameter.
- The velocity increases with an increase in the Permeability of the porous medium
- parameter.
- Increasing the Prandtl number substantially decreases the translational velocity and the
- temperature function.
- Increasing the Heat source parameter decrease both velocity and temperature.
- the velocity as well as temperature increases with an decrease in the Thermal radiation
- parameter.
- The velocity as well as concentration decreases with an increase in the Schmidt number.
- An Increase in the Soret number leads to decrease in the velocity and temperature.
- An increase in the Eckert number leads to increase in the velocity and temperature.
- The velocity as well as concentration decreases with an increase in the Chemical reaction parameter.

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